RDECOM

TARDEC

TECHNOLOGY DRIVEN. *WARFIGHTER FOCUSED.*

The Joint Center for Robotics and its JAUS Implementation Efforts

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Joint Center for Robotics
16 April 2008

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JCR Mission & Objectives

> ## *MISSION*
>
> *Serve as a focal point for military ground vehicle robotics <u>integration</u> efforts and to coordinate support across the life cycle spectrum (research, development, acquisition and sustainment) for all current and future military unmanned ground vehicles and robotic platforms*

Customer Support to RS-JPO & PM-FCS

Provide life-cycle expertise and support for current and future UGV systems

Industry Partnering for Relevant UGV Experimentation

Partner with local and national industry to bring cutting-edge technology to the war-fighter quicker through focused experiments with relevant military involvement

Academic Projects for Defense Robotics

Leverage & develop robotics technology and curriculum at local and national universities (*Long Term Strategic* and *Short Term Seedling* approaches)

UGV Virtual Systems Integration Laboratory (VSIL)

Partner with UGV stakeholders to develop & support unmanned systems throughout the life-cycle by the use of SIL activities at TARDEC and around the country

JCR Sponsored Outreach

Symposia, meetings, competitions, experiments, speaker service, etc.

TARDEC JCR Robotics

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TARDEC

"White Hat" Organization -
Understand the needs of the user
and create partnerships with
Academia, Industry and OGA

ARL

SPAWAR

DARPA

ONR
Revolutionary Research . . . Relevant Results

JCR

TRADOC

TPM-UGV

NAVEOD

Intelligent Ground Systems

Projects & Cells

CAST	SACR	RVCA	UGV

TARDEC Robotics

Mission

Integrate, Explore, and Develop Robotics, Network and Control Components with a Focus on Customer Driven Requirements to Provide Full System Solutions to the War Fighter

Technology Components

Academic Partnerships

Integration →

Demonstrators

RVCA ATO

UGV

Robotic Decontamination

RF Stryker

UGV

SME Defined Scenarios →

Military Relevant Test & Experimentation

Robotics Collaboration and RVCA ATO Experimentation

ODIS T-3

Convoy Active Safety Technologies War Fighter Experimentation #1

Tech Transfer →

Transition and Requirements Development
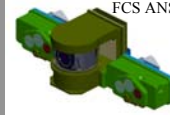

Future Force MULE

Initial Capabilities Document (ICD)

FCS MULE

FCS ANS

FCS JTRS

Current Force Convoy Operations

Integration Technology Development Lessons Learned to Enable Early Technology Insertion →

Solving Tomorrow's Challenges Today

Teleoperation

Protection | **Safe Operations**

Bandwidth | **Power & Energy**

Planning | **Classification**

Affordability | **Latency**

Convoy | **Weaponization**

Behaviors | **Sensing**

OCU | **Mobility**

Resolution | **Interoperability**

Payloads

UGVI Focus Areas

Tactical behaviors

Safe Operations and 360° SA
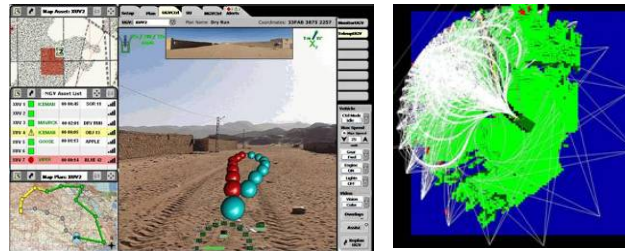
Platform Mobility

UGV – Soldier Interfaces

Autonomous Control

High-Speed Tele-operation
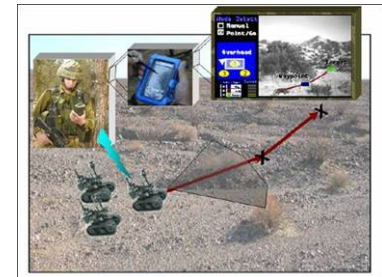
Arm and Manipulator Articulation

Communications

Power Management

Fuel Cell

Air — Hydrogen

Exhaust

JP-8 Fuel

Reformer
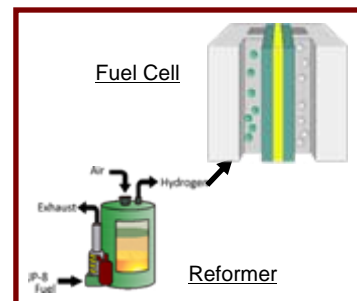
Non-LOS SA

FY07 UGVI Activities

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TARDEC

Industry Partnerships

Quantum Signal, LLC — Signal Processing Solutions
Ford
GM
DELPHI
Think-A-Move
GENERAL DYNAMICS — Strength On Your Side
POLARIS
OSHKOSH
Foster-Miller
JOHN DEERE
PERCEPTEK, Inc.
JADI
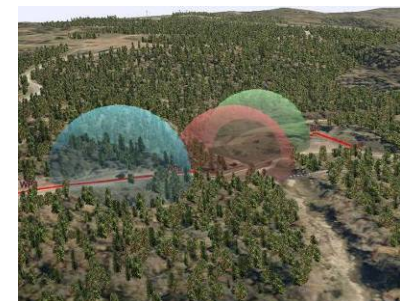
Government Partnerships

FUTURE COMBAT SYSTEMS — One Team-The Army/Defense/Industry

Academia Partnerships

MICHIGAN
S (Michigan State)
UNIVERSITY OF DETROIT MERCY
Lawrence Technological University
Georgia Institute of Technology
WAYNE STATE UNIVERSITY
MIT
Carnegie Mellon
Virginia Tech
ARMY
AU (Auburn)

Outreach Activities

FIRST
IGVC — Intelligent Ground Vehicle Competition

Top Level Breakdown

- UGV 3%
- Autonomy 5%
- Zipper Mast 2%
- IGS Radar Development Effort 3%
- Negotiator Arm 1%
- Community Outreach 2%
- West Point 0%
- MSU 5%
- WSU 2%
- LTU 3%
- MIT 1%
- U of M 8%
- U of M Dearborn 1%
- Oakland 2%
- Auburn 4%
- UD-Mercy 2%
- In House Expenditures 21%
- PEO GCS/RS JPO Support 11%
- CAST Program 15%
- VSIL Development and Support 9%

Technical Focus Area Breakdown

- Arm and Manipulator Articulation 3%
- Communications Quality-Of-Service 3%
- Tactical Behaviors 5%
- Non-LOS Situational Awareness 6%
- Power Management 7%
- High-Speed Tele-Operation 6%
- Autonomous Controls 9%
- Platform Mobility 11%
- Safe Operations and 360° SA 34%
- UGV – Soldier Interfaces 16%

Planned FY08 UGVI Activities

Top Level Breakdown

- Camp Grayling/Selfridge Test Facilities 1%
- JC-UGV Center Contracting Support 1%
- Seedling/Industry Partnerships 2%
- Knowledge Base for Defense Robotics 3%
- In House Expenditures 18%
- Robotic Communications 7%
- Community Outreach 2%
- PEO GCS/RS JPO Support 15%
- GRRC(UM, WSU, et al.) 32%
- CAST Program 8%
- VSIL Development and Support 6%
- Auburn 1%
- LTU 1%
- UD-Mercy 1%
- USMA 1%
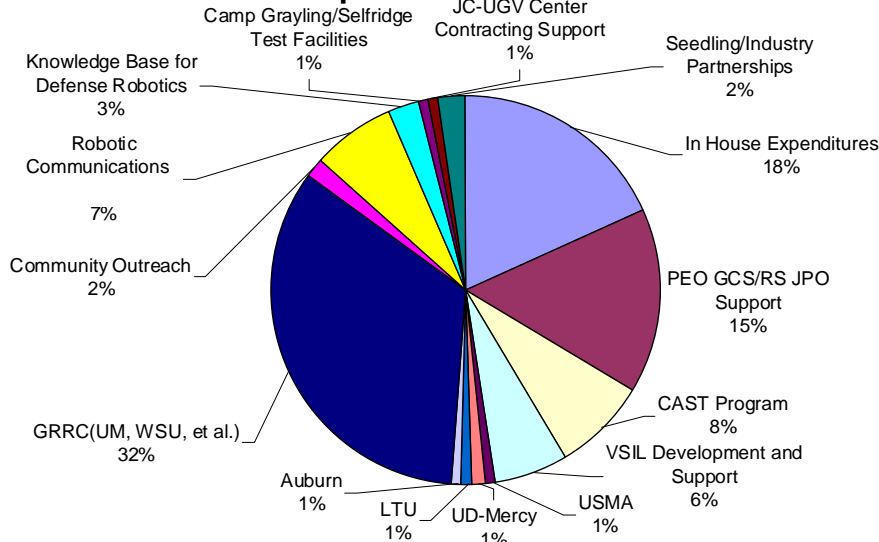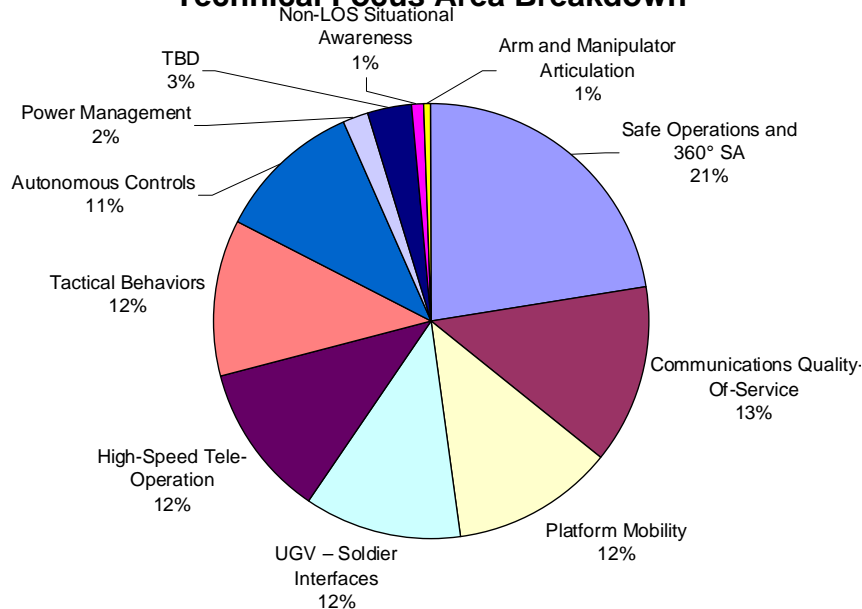
From Research to the Soldier

The University of Michigan, other participating universities, companies, and organizations will work within a tech transfer ecosystem to focus research on technologies which demonstrate a clear path to the soldier

The Research Continuum

Under the TARDEC umbrella, The GRRC will direct research projects and partnerships that:

1. Focus on TARDEC priorities
2. Meet stringent requirements for a focus on the solider
3. Maintain educational research standards
4. Can deliver tangible results (prototypes, demonstration units, etc)

Basic Science

TARDEC WSU U-M MSU Other Universities

GRRC Executive Committee Filter
Researchers
Project and Proposal Evaluations
Commercialization Plan
TARDEC Delivery to the Soldier

Key Partners

Industrial Advisory Board Members

U-M Tech Transfer Organizations ZLI, OTT, etc.

Commercialization Organizations MEDC, Ann Arbor SPARK

Technical Focus Area Breakdown

- Non-LOS Situational Awareness 1%
- TBD 3%
- Arm and Manipulator Articulation 1%
- Power Management 2%
- Safe Operations and 360° SA 21%
- Autonomous Controls 11%
- Tactical Behaviors 12%
- Communications Quality-Of-Service 13%
- High-Speed Tele-Operation 12%
- Platform Mobility 12%
- UGV – Soldier Interfaces 12%

Unmanned Ground Vehicle Research Curriculum

Breadth in Engineering

Breadth beyond engineering

Engineering Core

Management/Systems

Engineering Specialties

Overview and Capstone Project

Teamwork & Leadership

Depth in engineering
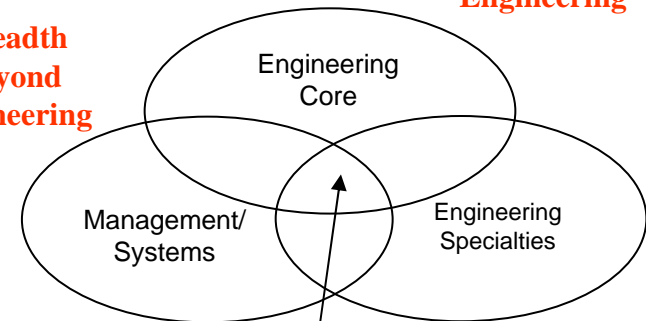
UGVI – Academic Success Stories
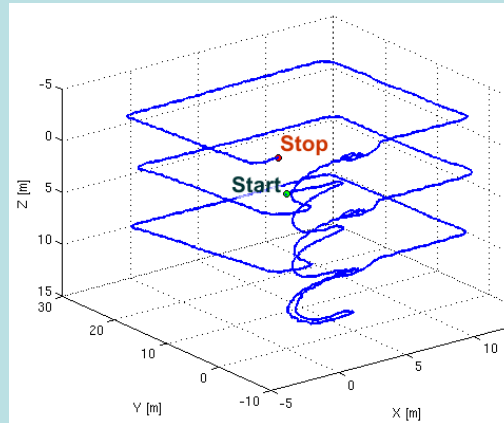
Oakland University

University of Michigan
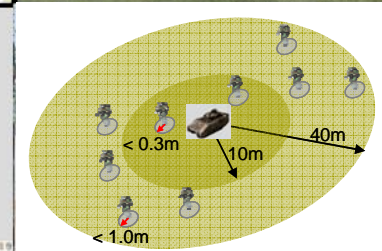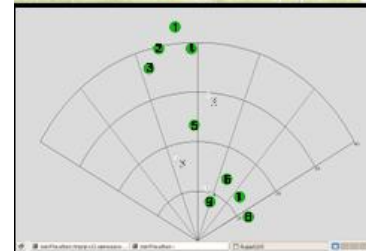
Auburn University
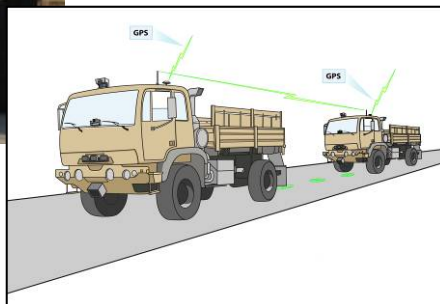
*Lawrence Technological University*
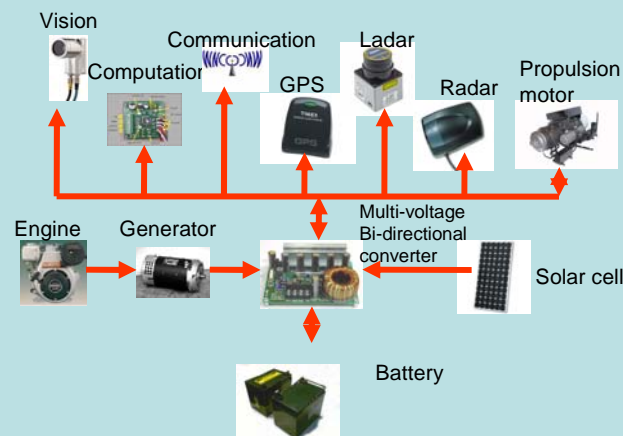
UGVI Sponsored Outreach Events

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2ND TARDEC Robotics Quarterly: Power Generation and Propulsion for Robotics systems with Dr. Mark Ehsani Texas A&M University; Dr. Thomas Jahns, University of Wisconsin; and Dr. Robert Fletcher, Lawrence Tech University. **07 JAN 08** ~~COMPLETED~~

1ST Robotic Vehicle Life Cycle Conference: This event will feature networking opportunities, exhibits and live demonstrations. Presentations will focus on US Army/US Marine Corps Land-based Robotics activities and will feature outstanding guest speakers from both Government and Industry **12-13 AUG 08**.

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP		FY09
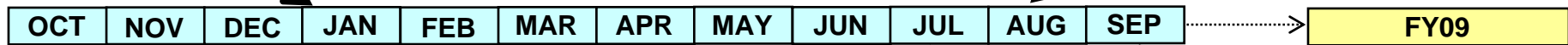
RET Day: Robotics, Engineering and Technology (RET) Day is being held at the Utica Community Schools Instructional Resource Center and is designed to introduce high school and middle school students to technology based careers through interactive demonstrations with some of today's current and future robotic systems. **4-6 DEC 07** ~~COMPLETED~~

5TH TARDEC Robotics Quarterly: Robotic that emulate Animals. **SEP 08**

4TH TARDEC Robotics Quarterly: JCR Academic Program Review. **JUL 08**

FIRST Robotics: The FIRST Robotics Competition involves teams of mentors and high school students who collaborate to design and build a robot in six weeks. This robot is designed to play a game, which is designed by FIRST and changes from year to year. **MAR 08** ~~COMPLETED~~

3RD TARDEC Robotics Quarterly: Advances In Autonomous Mobility in Complex Environments with Charles Reinholtz, Embry-Riddle Aeronautical University; John Beck, Oshkosh Corporation; Johann Borenstein, University of Michigan. **07 APR 08** ~~COMPLETED~~

IGVC: The Intelligent Ground Vehicle Competition (IGVC) is being held on Oakland University, it is a multidisciplinary exercise in product realization that challenges college engineering student teams to integrate advanced control theory, machine vision, vehicular electronics, and mobile platform fundamentals to design and build an unmanned system. Teams from around the world focus on developing a suite of dual-use technologies to equip ground vehicles of the future with intelligent driving capabilities. **30 MAY – 02 JUN 08**

Planned Outreach Activities (FY09):

Michigan FIRST Robotics Sponsor (MAR 2009)

17th Annual IGVC (JUN 2009)

2ND Robotic Vehicle Life Cycle Conference (AUG 2009)

Macomb County High School Robotics Day (DEC 2009)

UGV Indoor Navigation & Cooperation Competition (2009)

Convoy Active Safety Technologies

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Project Goals

- Enhance safety & survivability for military convoys
- Retrofit robotic kit for current force trucks
- Affordability ($10-20k) target cost per vehicle
- Auto pilot manned or unmanned operation

Path Ahead

- WE2 to test limited visibility environments, line haul speeds, multi-vehicle testing and obstacle avoidance
- Momentum at CASCOM & ARCIC for new requirements
- Solicitation of program office sponsorship

Partners:

RDECOM TARDEC JC-UGV

OUSD(ATL)PSA/LW&M JGRE

TRADOC CASCOM

PEO-CS/CSS PM MTV

PEO-GCS RS-JPO

Sustainment Battle Lab

Simply User Interface

COTs Equipment

GPS

Communications

LADAR

Color Cameras

RADARS
LADAR
Ground Speed Sensors
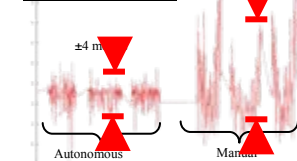
Warfighter Experiment 1 Accomplishments:

- Warfighter Experiments driven by Battle Lab performance metrics
- WE1: 7 week experiment testing 12 drivers through 8 hours of convoy ops
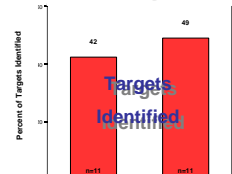- Data included situational awareness, fatigue, rear end avoidance, cognition and convoy integrity

Benefit for the Warfighter

Gap Distance Performance

±18 meters

±4 meters

Autonomous   Manual

4 fold improvement

Percent of Targets Identified

42   49

Targets Identified

OFF   ON

+ 20%

Dual Interface: Soldier Machine Interface

Soldier Machine Interface

- Route Information
  - Checkpoint Locations
  - Current position
  - Route Display/Maps
  - Driving Instructions
- Tactical Overlays
  - Danger Areas
  - Teammate Locations
- Automatic Cautions and Warnings
  - Approaching Danger Zone
  - Tie into Other Potential Payloads
- Sharing Video Across Assets
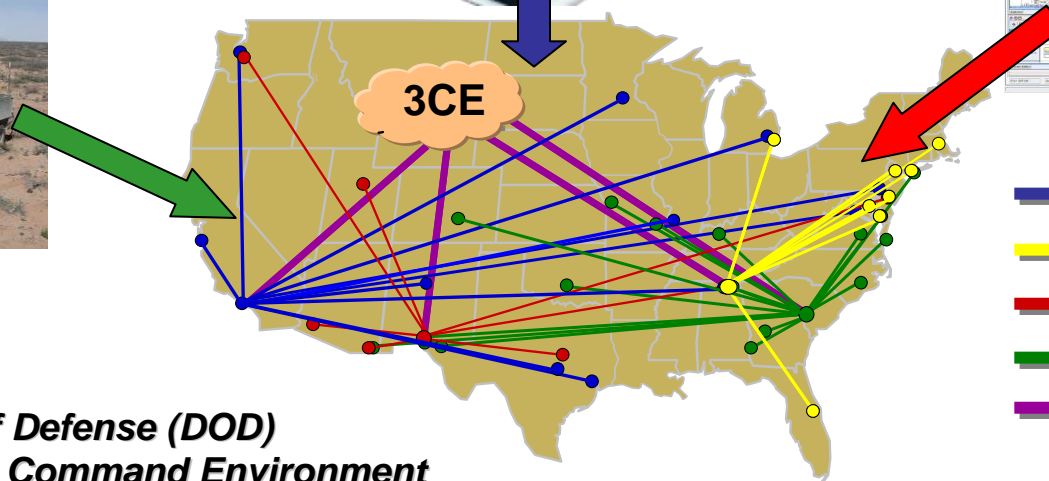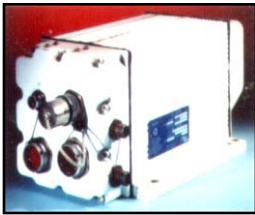
Improved Situational Awareness Opens Opportunities

- Advance Notification of Danger Areas
- Increased Lethality Via improved reaction time or Remote Controlled Turret
- UAV Collaboration for Forward, Rear and Flank Security

Manned/Unmanned Vehicle SIL

Live **Virtual** **Constructive**

3CE

Legend?

- LSI
- RDECOM
- ATEC
- TRADOC
- 3CE Link

3CE= Department of Defense (DOD)
Cross Collaborative Command Environment

Joint Forward Area Automated Decontamination (JFAAD)

Joint Forward Area Automated Decontamination (JFAAD) project assesses the process required to implement a robotic automation of vehicular decontamination methodology prototyped on the TAGS robotic platform. TARDEC Collaborative UAV/UGV program is using the TAGS robotic platform as JAUS standard protocol. The TAGS is a Skunk-Works platform that is a high-performance, high-speed, high-mobility JAUS-compliant semi-autonomous unmanned ground vehicle (UGV) with modular payload capabilities that is transitioning to JAUS standard. TAGS uses the latest version of the JAUS World Model message.
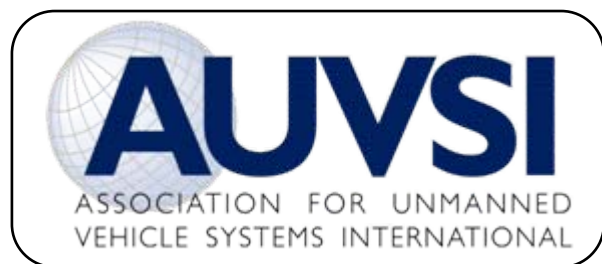
Robotic Patient Extraction

- **JAUS Compliant Architecture**
- **"Point and click" interface**
- **Upper Body and Lower Torso control**

Intelligent Ground Vehicle Competition

Competition Purpose

Objective:

The objective of the competition is to challenge students to think creatively as a team about the evolving technologies of vehicle electronic controls, sensors, computer science, robotics, and system integration throughout the design, fabrication, and field testing of autonomous intelligent mobile robots.

Educational Benefits:

This competition has been highly praised by participating faculty advisors as an excellent multi-disciplinary design experience for student teams, and a number of engineering schools give credit in senior design courses for student participation.

Real-world Applications:

To advance and promote intelligent mobility for civilian and military ground vehicle applications. Intelligent mobility will provide the driver aids required for future Automated Highway Systems (AHS) and Intelligent Transportation Systems (ITS). For military systems, autonomous mobility will enable unmanned combat vehicles to perform high risk operations and multiply the force effectiveness of manned systems. IGVC objectives for military applications focus on goals established in the Department of Defense Joint Ground Robotics Enterprise (JGRE). IGVC promotes core intelligent mobility competencies in perception, planning, actuation and mechatronics.

Competition History

1993 Autonomous Challenge

1995 Design Competition

1999 – 2000 Road Debris Course

1999 – 2001, 2003 Follower The Leader

2001 Navigation Challenge

2006 JAUS Challenge

15 Years and Running

School	Teams	Competitions
Arizona State University	1	1
Bluefield State College	7	7
Bob Jones University	3	3
Brigham Young University	2	2
California State University – Northridge	2	2
Case Western Reserve University	1	1
Cedar College	3	3
Cedarville University	4	4
Cleveland State University	2	2
Colorado School of Mines	3	3
DeVry Institute of Technology – Calgary	3	3
École de technologie supérieure	6	6
École Polytechnique de Montréal	1	1
Elizabethtown College	2	2
Embry-Riddle Aeronautical University	3	3
Georgia Institute of Technology	4	4
Hosei University	12	11
Kettering University	2	2
Lawrence Technological University	11	5
Michigan Technological University	5	5
Northern Illinois University	6	6
Oakland University	24	15
Princeton University	3	3
Rochester Institute of Technology	2	2
Stony Brook University	1	1
Tennessee State University	2	2
The City College of New York	1	1
The College of New Jersey	2	2
The Ohio State University	3	3
Trinity College	8	8

School	Teams	Competitions
U.S. Military Academy – West Point	5	4
University of Alberta	8	8
University of Central Florida	7	5
University of Cincinnati	19	15
University of Colorado – Boulder	6	6
University of Colorado – Denver	11	11
University of Delaware	1	1
University of Delhi	1	1
University of Detroit Mercy	8	6
University of Florida	3	3
University of Illinois – Chicago	1	1
University of Maine	2	2
University of Maryland – BC	1	1
University of Maryland – College Park	1	1
University of Massachusetts – Lowell	2	2
University of Michigan – Ann Arbor	2	2
University of Michigan – Dearborn	11	7
University of Minnesota – Twin Cities	7	7
University of Minnesota – Duluth	2	2
University of Missouri – Rolla	4	3
University of North Dakota	2	2
University of Texas – Arlington	2	2
University of Texas – Austin	2	2
University of Tulsa	11	8
University of Wisconsin – Madison	4	4
Virginia Tech	33	12
Wayne State University	1	1
West Virginia University	4	4
Wright State University	1	1

291 Teams from 59 Universities in 4 Countries

Autonomous Challenge

A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while staying within the 5 mph speed limit, and avoiding the obstacles on the track.

Judges will rank the entries that complete the course based on shortest adjusted time taken. In the event that a vehicle does not finish the course, the judges will rank the entry based on longest adjusted distance traveled. Adjusted time and distance are the net scores given by judges after taking penalties, incurred from obstacle collisions, pothole hits, and boundary crossings, into consideration.

AWARD MONEY:
$ 9,500

Design Competition

Although the ability of the vehicles to negotiate the competition courses is the ultimate measure of product quality, the officials are also interested in the design strategy and process that engineering teams follow to produce their vehicles. Design judging will be by a panel of expert judges and will be conducted separate from and without regard to vehicle performance on the test course. Judging will be based on a written report, an oral presentation and examination of the vehicle.

Design innovation is a primary objective of this competition. Two forms of innovation will be judged: First will be a technology (hardware or software) that is new to this competition; and Second will be a substantial subsystem or software upgrade to a vehicle previously entered in the competition. In both cases the innovation needs to be documented, as an innovation, clearly in the written report and emphasized in the oral presentation. Either, or both, forms of innovation will be included in the judges' consideration.

AWARD MONEY:
$ 6,500

Navigation Challenge

Navigation is a practice that is thousands of years old. It is used on land by hikers and Soldiers, on the sea by sailors, and in the air by pilots. Procedures have continuously improved from line-of-sight to moss on trees to dead reckoning to celestial observation to use of the Global Positioning System (GPS). The challenge in this event is for a vehicle to autonomously travel from a starting point to a number of target destinations (waypoints or landmarks) and return to home base, given only the coordinates of the targets in latitude and longitude.

AWARD MONEY:
$ 8,250

JAUS Challenge

The Joint Architecture for Unmanned Systems (JAUS) is a set of standardized messages suitable for controlling all types of unmanned systems, and is soon to become an Aerospace Standard of the Society of Automotive Engineers (SAE). IGVC officials and sponsors believe that it would be valuable for student teams to become exposed to and familiar with JAUS. The intent is to start at a very simple level and increase the complexity in an incremental manner at successive competitions. There are two aspects to JAUS Challenge: (1) a written/oral presentation which will be added to the Design Competition and (2) a practical demonstration.

AWARD MONEY:

$ 500 PER UNIVERSITY

2006 JAUS Challenge Results

Level I Challenge:

Bluefield State College	Anassa II
Case Western Reserve University	Roberto
École de technologie supérieure	RS3
Hosei University	Omnix 2006
Lawrence Technological University	H2Bot
Trinity College	ALVIN VII
University of Alberta	ARVP
University of Cincinnati	Bearcat III
University of Colorado - Denver	PUMA
Virginia Tech	Gemini

28 Schools

32 Teams

2007 JAUS Challenge Results

Level I Challenge:

Bob Jones University	Balthasar
Rochester Institute of Technology	Overlord
University of Minnesota – Twin Cities	AWESOM
University of Texas – Austin	BlastyRAS
University of Wisconsin – Madison	ReWIRED

Level II Challenge:

École de technologie supérieure	RS3
Hosei University	Omnix 2007
Lawrence Technological University	H2Bot II
University of Cincinnati	Bearcat Cub
Virginia Tech	Polaris

27 Schools

31 Teams

2008 JAUS Challenge

Level III Challenge:

Will demonstrate vehicles accept the Navigation Challenge waypoints and execute them in the prescribed order during their attempts at the Navigation Challenge. Each attempt at the Navigation Challenge using the JAUS messages will have a different order for the waypoints. Level 1 must be implemented in order to participate in the Level 2 challenge. The team will also have to pre-qualify their JAUS implementation prior to attempting the Navigation Challenge. If a team does not qualify with JAUS for the Navigation Challenge, they will be allowed to attempt the Navigation Challenge without using JAUS.

Rookie-of-the-Year

The Rookie-of-the-Year Award will be given out to a team from a new school competing for the first time ever or a school that has not participated in the last five competitions. To win the Rookie-of-the-Year Award the team must be the best of the eligible teams competing and perform to the minimum standards of the following events. In the Design Competition you must pass Qualification, in the Autonomous Challenge you must pass the Rookie Barrel and in the Navigation Challenge you must make three waypoints.

AWARD MONEY:
$1,000

Grand Award

The Grand Award is given to the team with the best overall performance in all three events. The Grand Award trophies will be, presented to the top three teams that perform the best overall (combined scores per below), in all three competitions. For each competition, points will be awarded to each team, below is a breakdown of the points:

AWARDS:
LESCOE CUP
LESCOE TROPHY
LESCOE AWARD

The 16TH Intelligent Ground Vehicle Competition

Rochester, Michigan
May 30 - June 2, 2008

AUTONOMOUS CHALLENGE: Vehicles must negotiate an outdoor obstacle course in full autonomous mode.

NAVIGATION CHALLENGE: Vehicles must maneuver using GPS coordinates to target destinations while avoiding obstacles.

DESIGN COMPETITION: Submit a written report, make an oral presentation and demonstrate the vehicle.

JAUS CHALLENGE: Design your vehicle to accept the open architecture for unmanned systems.

Over $25,000 in STUDENT AWARDS

Questions

WWW.IGVC.ORG